A LOOK AT RESEARCH PRODUCTIVITY: EXAMINING THE RELATIONSHIPS BETWEEN PUBLICATIONS, CITATIONS, AND RESEARCH AND DEVELOPMENT EXPENDITURES

By
Yoke Dellenback

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Abstract

A faculty member's publications are one of the most important pieces of evidence of research output. They serve as a form of communication of scientific discoveries, innovations and findings while demonstrating the authors are subject matter experts in their fields. At the same time, research institutions view the number and quality of publications on a faculty member's curriculum vitae as a critical return on investment and a measure of the faculty member's research productivity, impact and academic achievements for the tenure and promotion process. There were two research objectives for this thesis. The first objective was to look at the research productivity at the institutional level by examining research & development (R&D) expenditures and publication output. The second objective was to look at research productivity at the faculty level by exploring a faculty member's publication output, citations of the publications and R&D expenditures. The questions explored were: Were R&D expenditures related to publication count at the institutional level? Were a faculty member's R&D expenditures related to his/her publications and citations? Were there direct correlations among these variables: publications, citations, and R&D expenditures? The relationships among the variables were explored using regression analysis. The analyses indicated significant relationships between R&D expenditures and publications at the institutional level and among R&D expenditures, publications and citations at the faculty level.

Primary Reader: Jeffrey E. Kantor

TABLE OF CONTENTS

List of Tables

List of Figures

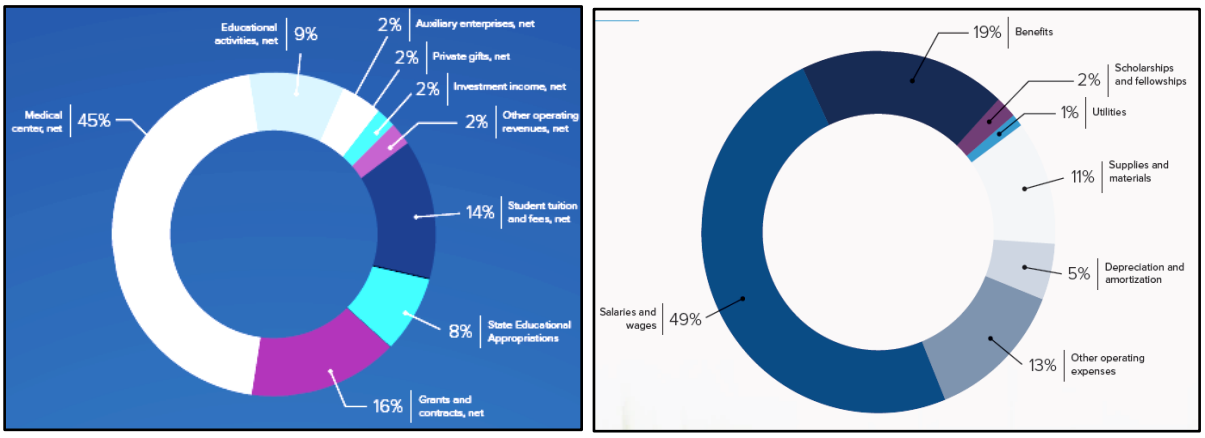
1. INTRODUCTION

1.1 Institutional View

With the ever-changing landscape and environment surrounding federal funding and the decline in state appropriations, research institutions are compelled to compete globally to seek out other funding sources to diversify their revenue portfolio to cover expenditures (See Figure 1) such as salaries and wages, the biggest expense category. At same time, they are also hoping to improve the institution's prestige, reputation and rankings to attract "cream of the crop" students and new faculty. A research institution bears the fiduciary responsibility and is accountable to the stakeholders (e.g., federal, state or local government, private foundations, donors and taxpayers) when accepting external funding for sponsored projects. The research institution must also ensure the funds are spent appropriately while complying with federal and state law, regulations and statutes, institutional policies and sponsors' terms and conditions.

Figure 1

Examples of Revenue and Expenditure Types.



1.2 Faculty View

Meanwhile, the faculty member, as the principal investigator, must conduct the work ethically and with integrity while considering the principles of responsible conduct of research.

They are scientifically and programmatically responsible for the research project and are also responsible for disseminating and publicizing any scientific findings and discoveries from the project while balancing other duties and responsibilities such as teaching, doing public service and mentoring undergraduates, graduate students and post-doctoral scholars. A faculty member's numbers and the quality of publication are some of the most important pieces of evidence of research output. It is an opportunity for the faculty member to prove to themselves and others that they are subject matter experts in their fields while presenting "a description of the work undertaken, report of the results, and an honest and open assessment of the findings" (Steneck, 2007, p. 134).

1.3 Why Publish Scientific Findings?

There are several salient factors to publishing scientific findings since a faculty member's publications are also the vehicle for the "communication and the exchange of research findings and results" (Ramsden, 1994, p. 207), and one of the factors is to promote and ensure accountability. Since the public often supports the research when the research is federally funded, they should be able to access information on the research to see how the funding is being used. Another salient factor to publishing results is that it allows for researchers and scientists to share and communicate their findings and discoveries. Another aspect of publications is that it establishes a researcher's reputation and professional standing, which could lead to opportunities to collaborate with other researchers as well as industry. Finally, when scientific results are published in peer-reviewed journals, other researchers can replicate those published results and cite the publications to support their own research thus increasing the original author's visibility and influence in the scientific community. The frequency of a faculty member's publication being cited (i.e., citation count) can be used to assess the level of research impact for his/her

specific research discipline. For that reason, citation counts are an important contributing factor for grant applications, employment, tenure, promotion, collaborating and publishing opportunities.

1.4 Reported R&D Expenditures and Publication Output

The National Science Foundation published the R&D expenditures on its website and reported that the R&D expenditures for Fiscal Year (FY) 2018 increased by 5% from FY 2017, reaching a total of approximately $79 billion dollars, and that is 118% increase from FY 2002. Figures 2, 3, 4 and 5 display the FY 2018 R&D expenditures by major R&D fields and sub-fields. Then, in December 2019, the National Science Board's Science and Engineering Indicators reported that the global publication output was 2.6 million for 2018 and the United States' publication output was 422,808 or 16.54% of the global total publication output. Figures 6 and 7 show the United States' 2018 publication output by fields in percentages and in numbers.

1.5 Closing Statement

Two datasets were created by utilizing available data to explore research productivity at the institutional level (Table 1) and at the per faculty level (Figure 8). Both datasets were analyzed using regression analysis at a .05 level of probability to determine whether the relationships among the variables were statistically significant.

Figure 2

R&D Expenditure by Major R&D Fields

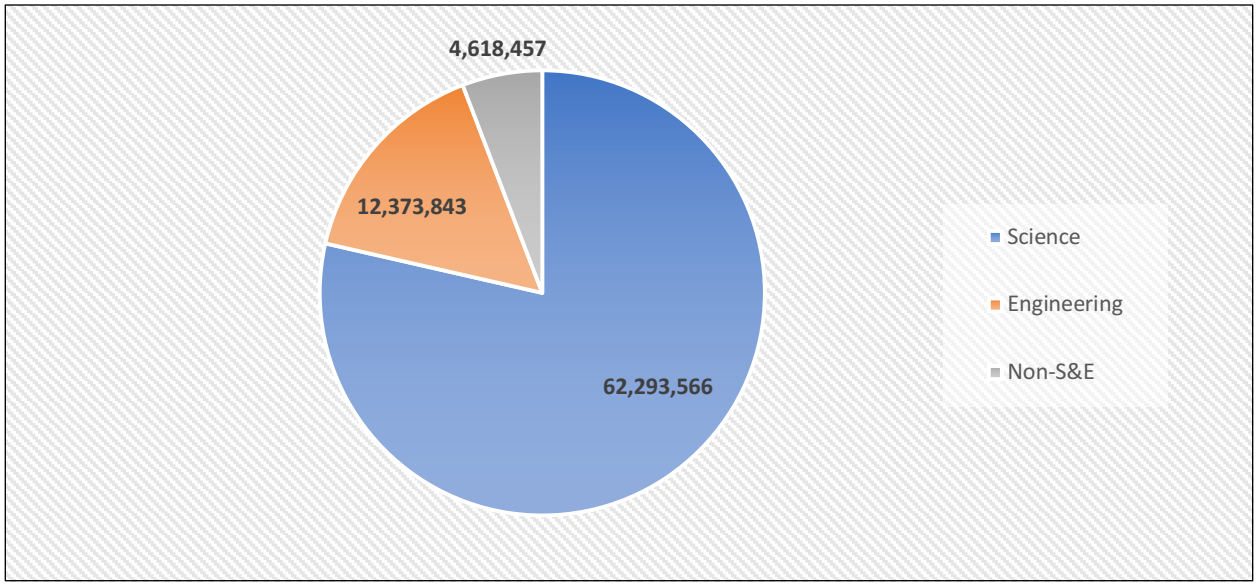


Figure 3

R&D Expenditure by R&D Sub-Fields in Sciences

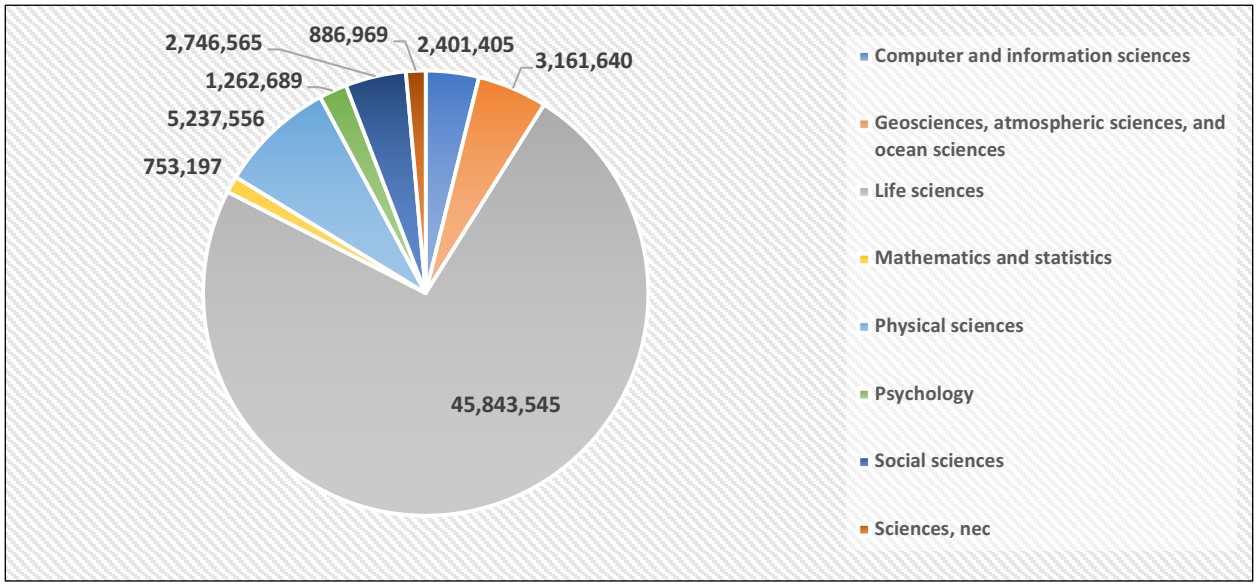


Figure 4

R&D Expenditure by R&D Sub-Fields in Engineering

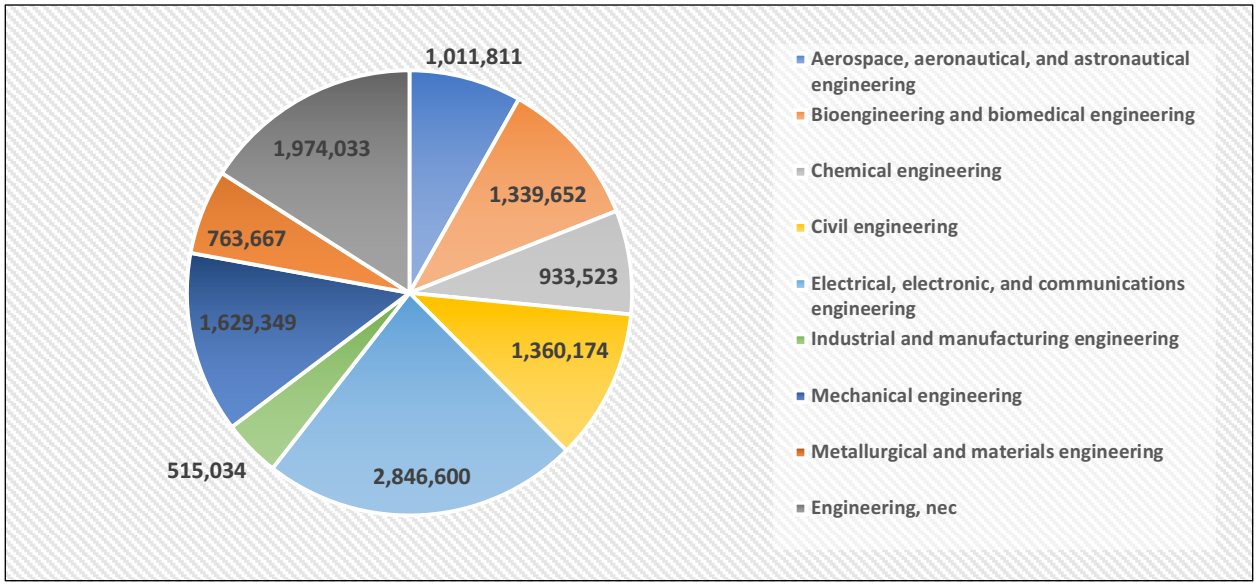


Figure 5

R&D Expenditures by R&D Sub-Fields in Non-Science and Engineering

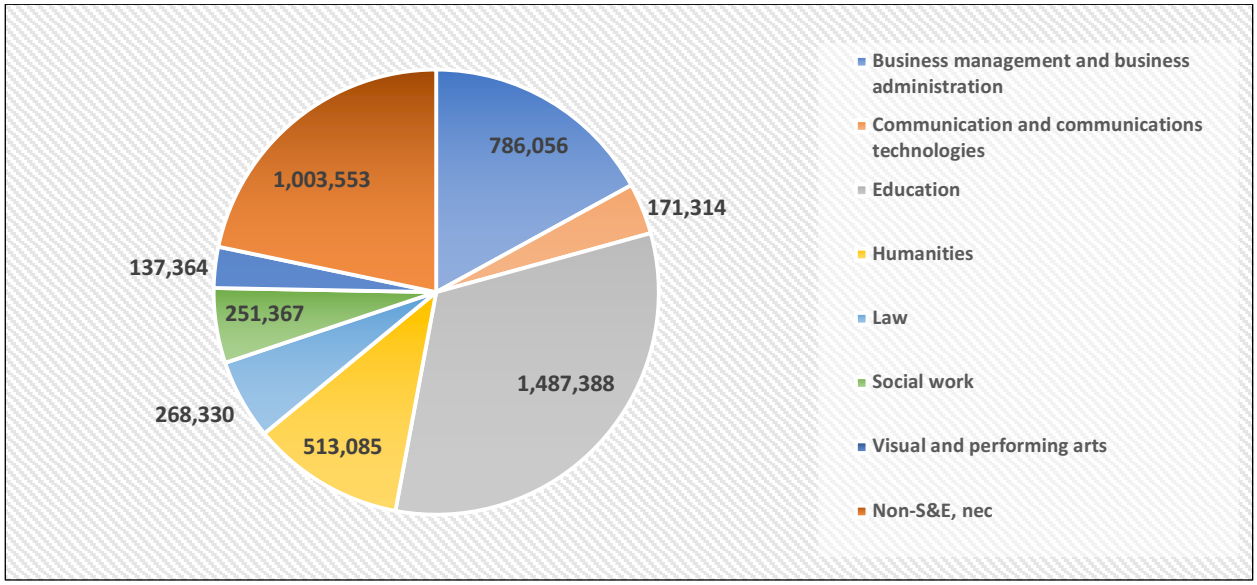


Figure 6

Publication Output by Fields in Percentages FY 2018

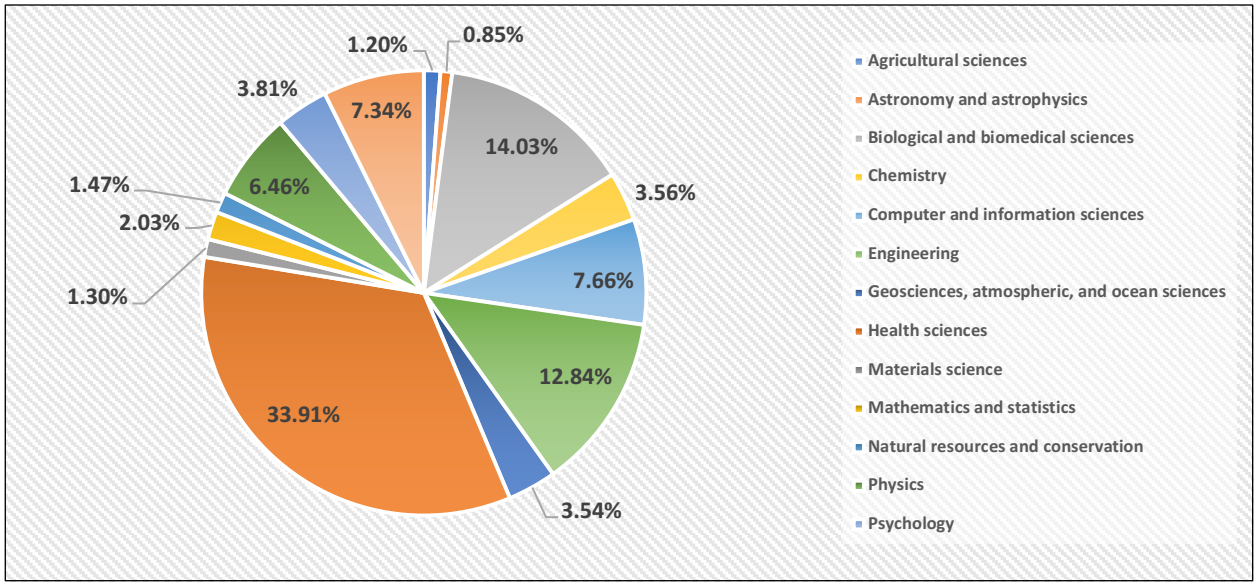
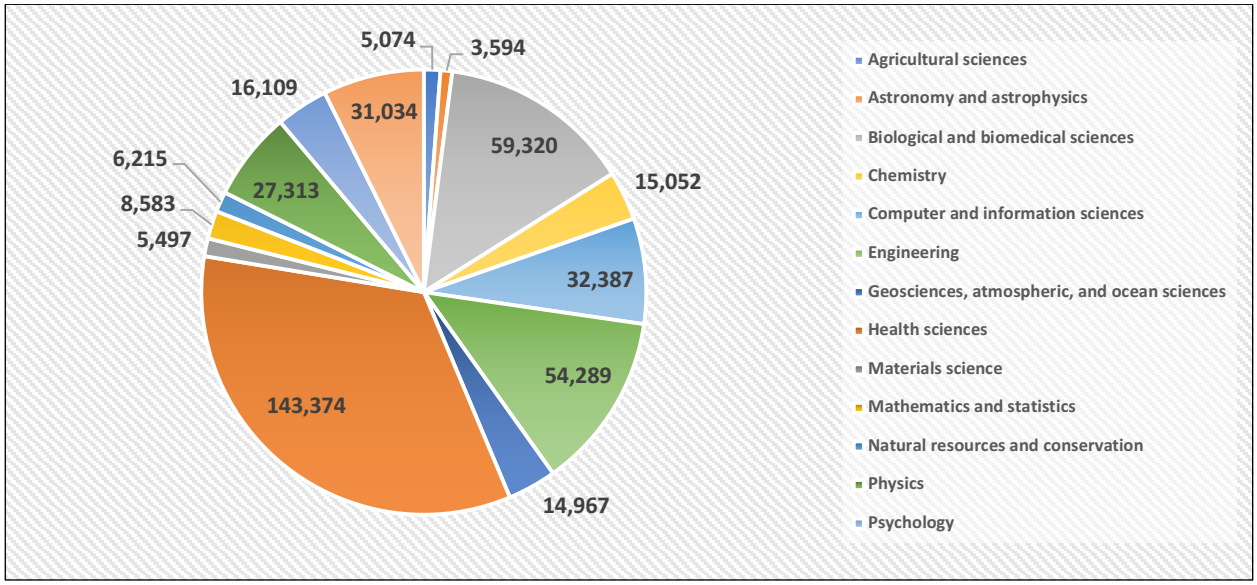


Figure 7

Publication Output by Fields in Numbers FY 2018



2. REVIEW OF THE LITERATURE

In an institution's faculty "selection, appointment, promotions and research grants approval processes" (Jawaid, 2016, p. 1), the number of publications is viewed as a critical return on investment measure on a faculty member's productivity, achievements and "academic distinction" (Ramsden, 1994, p. 207). According to Schimanski and Alperin (2018), an institution's tenure and promotion requirements and processes have evolved to emphasize research and publications. The authors referenced a survey with faculty in an R1 institution where the faculty perceived that the relative importance of research was weighted at 65%, teaching at 25.6% and service at 8.7% during the tenure and promotion review process. In that instance, faculty may feel the pressure to publish and focus their attention on research and neglect the other two areas even though the institution may have policies on fair, equitable and transparent review on teaching, research and service. In addition, the faculty felt that those percentages should be changed to 49.3% for research, 37.3% for teaching and 13.5% for service, shifting the emphasis towards teaching and service.

There are institutions that have explicit publication and performance expectations that a faculty member is required to meet for tenure and promotion. For instance, the University of Missouri expects their faculty "to produce an average of 2 publications per year in high quality refereed scholarly journals" (University of Missouri, 2020). The University of South Florida (USF) have a tenure probationary period of 7 years and expects its humanities faculty to "publish 2-4 high quality, predominantly refereed book chapters or articles and should have approximately 10 high quality, predominantly refereed publications" (University of South Florida, 2014). Virginia Tech did not specify the number of publications required for faculty promotion and tenure; however, there is an emphasis on publishing in elite journals and

"research publication must be of enough substance to garner growing national recognition for the faculty member's program of research" (vt.edu, 2020).

Schimanski and Alperin (2018) further asserted that research institutions may have standard guidelines and checklists pertaining to the major areas (i.e., research, teaching and service) essential to the review and evaluation process of a faculty's tenure and promotion. Those guidelines and checklists appeared to place higher weight on research as compared to teaching and service. Linfield College, for example, has a faculty handbook on tenure and promotion where there is a focus on teaching effectiveness. However, there is an extensive section on professional achievement that specifies the necessary items "for tenure and promotion for both associate and full professor" (Linfield College, 2016, p. 4) with the first item as "research and scholarship leading to peer-reviewed publication of books (including textbooks or articles or chapters in edited books), monographs, or professional journal articles in Sociology or Anthropology, or interdisciplinary work in related fields" (Linfield College, 2016, p. 4)

Research institutions would also use publication output as an indicator to determine an institution's and its faculty's research productivity and performance for resources and infrastructure planning and allocation. McAllister and Wagner (1981) utilized two large data sources from the National Science Foundation and CHI Research to study the link between research expenditures and research output (i.e., quantity of scientific journal articles). The authors pointed out that there was a study done to investigate "the relationship between NIH funding and biomedical publication output for major NIH funded institutions" (McAllister & Wagner, 1981, p. 4), and there was a positive correlation between the variables of NIH funding and publication output. For their study, McAllister and Wagner analyzed their data using

correlation and regression analysis and found a strong correlation between research expenditures and publication output.

Additionally, Teodorescu (2000) did a study on the publication productivity of faculty across 10 countries (Australia, Brazil, Chile, Hong Kong, Israel, Japan, Korea, Mexico, the United Kingdom and the United States). The author found that faculty members in research institutions are expected to conduct research as part of their academic performance evaluation while cultivating and producing new ideas and training students in research methods. He further asserted that most of the studies on research productivity occurred in developed countries such as the United States, United Kingdom and Australia. For his study, he developed a survey for respondents to provide information on "the number of journal articles and chapters on academic books that had been published in the three years prior to the survey" (Teodorescu, 2000, p. 206). He then did the analysis based on three blocks of variables - Individual Attributes (e.g., age and gender), Individual Accomplishments (e.g., tenure status or amount of research funding received) and Institutional Attributes (e.g., salary or institutional financial and research support) - and discovered that individual accomplishments and achievement has a strong correlation with publication productivity. Teodorescu concluded that while there may be a distinct difference on the variables that correlates to publication productivity across research institutions globally, he found that accessibility to research grant funding and network opportunities in international professional conferences had a positive effect on publication productivity.

Sivertsen (2010) described a system implemented in Norway in 2005 using publication output as a performance indicator for funding and resource allocation and distribution. The main goal of this system was to have a multi-purpose database with all the "scientific and scholarly publications" (Sivertsen, 2010, p. 25) so that it can be accessed by institutions and the

government when making funding decisions and preparing annual reports, curriculum vitae and grant applications. The author further elaborated that each institution shares ownership of the database to ensure that the publication records are complete and consistent with the definitions and guidelines agreed by the institutions. The publications are counted with points given at the institutional level and that information is used to allocate "direct block funding" (Sivertsen, 2010, p. 26). The author concluded that institutions have the shared responsibility to facilitate research for their faculty members and research scientists, and the system is implemented to stimulate and encourage scientific output from institutions.

To complement publication output, research institutions could also use citation count as a performance indicator to measure a faculty member's reach, impact, influence and visibility in the scientific community. Carpenter, Cone and Sarli (2014) provided insights into a variety of metrics derived from publication data for measuring academic productivity. They added that these metrics provide "meaningful narrative" (Carpenter, Cone & Sarli, 2014, p. 1162) of a faculty member's "research and scholarly activities" (Carpenter, Cone & Sarli, 2014, p. 1162), and institutions can use them for various purposes such as academic promotions, recruitment, grant applications and departments' or institutions' annual reports.

Carpenter, Cone and Sarli (2014) continued with a discussion on what publication metrics are currently being used: publication numbers, author status (solo, first or last author), journal impact factor score, and citation numbers. Both the journal impact factor impact score and citation numbers are most commonly used to assess an author's research impact and influence. The authors then described citation analysis as a tool to determine "how often subsequent publications cite a specific publication" (Carpenter, Cone and Sarli, 2014, p. 1165). However, they cautioned the use of citation counts since there are more time for older

publications to build up citations counts as compared to newer publications. Another peculiar characteristic of citation count is that it "can be manipulated by deliberate self-citation or reciprocal citations by colleagues" (Carpenter, Cone and Sarli, 2014, p. 1166). They then introduced document-level metrics which captures data "to determine how a work is read online, downloaded, shared among others, commented upon, recommended, viewed and saved in online reference managers" (Carpenter, Cone & Sarli, 2014, p. 1168).

In the end, each performance indicator discussed has its nuance and usefulness for measuring research output, impact and productivity; however, one size does not fit all. Therefore, it is important for a research institution to be flexible and thoughtful when implementing and integrating various types of performance indicators, such as total R&D expenditures, publication output and citation count to measure research impact and productivity. This is to ensure fairness, transparency and consistency during an institution's review of its policies and also during its faculty members' academic performance evaluation.

3. PROBLEM STATEMENT

For this thesis**,** available data were used to explore research productivity at the institutional level by examining R&D expenditures and publication output and to also explore research productivity at the faculty level by exploring a faculty member's publication output, citations of the publications and R&D expenditures to answer the questions: Are R&D expenditures associated with research output (publications) at the institutional level? Are a faculty member's R&D expenditures related to publications and citations? Are there significant relationships among these variables: publication numbers, citation numbers, and R&D expenditures?

4. METHODOLOGY

4.1 Dataset No. 1: Institutional View

The first dataset, shown in Table 1, was created to look at the research productivity landscape at the institutional level and has the column headings: Year, Fractional Publication Count (i.e., fractional credit given for a publication for each institution proportion to the participating authors from each institution), Whole Publication Count (i.e., full credit given for a publication for each institution type that is on the author's list) and R&D Expenditures. This combination of variables – Total R&D expenditures with total whole publication count and total R&D expenditures with total fractional publication count – was analyzed through regression analysis. The data for the first dataset was taken from the National Science Board's Science and Engineering Indicators and the National Science Foundation's Higher Education Research and Development Survey.

Table 1

Publication Count, R&D Expenditures and Faculty Count: 2002-2018

Year	Fractional Publication Count	Whole Publication Count	R&D Expenditures (Dollars in million)
2002	319,308	358,181	36,383
2003	329,399	379,446	41,470
2004	353,853	407,443	44,839
2005	384,573	443,943	47,535
2006	385,515	448,696	49,645
2007	391,910	459,143	51,590
2008	393,979	463,386	54,114
2009	399,350	472,771	57,288
2010	408,817	486,363	61,287
2011	423,959	506,948	65,274
2012	427,997	517,473	65,873
2013	429,570	525,373	67,145

2014	433,192	535,617	67,351
2015	429,989	537,423	68,695
2016	427,265	541,080	71,894
2017	432,216	552,148	75,328
2018	422,808	548,847	79,436

4.2 Dataset No. 2: Per Faculty View

The second dataset, shown in Figure 8, was created by randomly selecting 75 institutions from 646 institutions from the National Science Foundation's Higher Education Research and Development Survey for Fiscal Year 2018 using the function {=rand()} in Excel. . The purpose of this smaller dataset was to explore the relationships between R&D expenditures, publication count and citations at the individual faculty level. The faculty count (with faculty status) for each institution was taken from the human resources data in Institute of Education Sciences-National Center for Education Statistics' Integrated Postsecondary Education Data System.

The total publication number was taken from the institution output from Web of Science's Advanced Search option based on the following criteria specified in the Advanced Search option.. The citation numbers for each institution was taken from the Create Citation

- Publication Year (PY) = 2018
- Organization-Enhanced Index (OG) = (Name of Institution)
- Region/Country (CU) = USA
- Custom Time Span = 2018 to 2018
- Language: English
- Document Type: Article

Report option available in Web of Science. Next, the publication (Web of Science) per faculty ratio was calculated for the 75 sampled institutions. The R&D expenditures per faculty was also calculated followed by the citation (Web of Science) per faculty. A regression analysis was done

on the second data set to determine if there was a statistically significant relationship at the .05 level among this combination of variables: R&D expenditures per faculty with publication count per faculty and R&D expenditures per faculty with citation per faculty.

Figure 8

75 Sampled Institutions ranked by R&D expenditures with Ratios: Publication per faculty, R&D Expenditures per faculty and Citation per Faculty

Institution	Carnegie Classification Control	Carnegie Classification Basic	Rank by R&D Expenditures	2016 R&D expenditures (in thousands)	Faculty Count (with faculty status)	Publication Count (Web of Science)	Sum of Times Cited (Web of Science	R&D Expenditures per faculty (in thousands)	Publication per Faculty (Web of Science)	Citation per Faculty (Web of Science)
Cornell U.	Private	Doctoral Universities: Very High Research Activity	13	1,071,621	1,831	7,613	55,670	585.27	4.16	30.40
Washington U., Saint Louis	Private	Doctoral Universities: Very High Research Activity	27	816,139	3,263	5,006	41,712	250.12	1.53	12.78
Michigan State U.	Public	Doctoral Universities: Very High Research Activity	32	715,290	2,794	4,916	26,485	256.01	1.76	9.48
U. Colorado Denver and Anschutz Medical Campus	Public	Doctoral Universities: Very High Research Activity	49	525,531	5,106	3,448	24,639	102.92	0.68	4.83
U. Georgia	Public	Doctoral Universities: Very High Research Activity	57	453,249	2,734	3,500	13,237	165.78	1.28	4.84
U. Kentucky	Public	Doctoral Universities: Very High Research Activity	63	393,034	2,553	2,928	14,839	153.95	1.15	5.81
Washington State U.	Public	Doctoral Universities: Very High Research Activity	71	360,522	1,709	2,330	11,742	210.95	1.36	6.87
Rockefeller U.	Private	Doctoral Universities: High Research Activity	73	353,142	85	676	8,176	4,154.61	7.95	96.19
U. Kansas	Public	Doctoral Universities: Very High Research Activity	74	339,046	2,448	2,771	14,994	138.50	1.13	6.13
Dartmouth C.	Private	Doctoral Universities: Very High Research Activity	76	323,927	751	1,875	11,046	431.33	2.50	14.71
Wayne State U.	Public	Master's Colleges & Universities: Medium Programs	99	238,859	1,633	2,286	11,437	146.27	1.40	7.00
U. Delaware	Public	Doctoral Universities: Very High Research Activity	119	186,192	1,243	2,011	10,526	149.79	1.62	8.47
U. Texas Medical Branch	Public	Special Focus Four-Year: Medical Schools & Centers	122	181,831	670	926	4,666	271.39	1.38	6.96
U. Houston	Public	Doctoral Universities: Very High Research Activity	123	177,484	1,318	2,252	10,951	134.66	1.71	8.31
U. Vermont	Public	Doctoral Universities: High Research Activity	143	129,921	1,296	1,316	8,793	100.25	1.02	6.78
U. Rhode Island	Public	Doctoral Universities: High Research Activity	156	104,490	779	785	3,742	134.13	1.01	4.80
Rensselaer Polytechnic Institute	Private	Doctoral Universities: Very High Research Activity	157	100,856	452	839	4,773	223.13	1.86	10.56
U. Texas, El Paso	Public	Doctoral Universities: Very High Research Activity	161	91,032	812	720	2,953	112.11	0.89	3.64
Cleveland State U.	Public	Doctoral Universities: High Research Activity	166	83,641	542	343	1,100	154.32	0.63	2.03
South Dakota State U.	Public	Doctoral Universities: High Research Activity	179	63,465	588	482	2,382	107.93	0.82	4.05
U. Massachusetts, Boston	Public	Doctoral Universities: High Research Activity	182	61,473	718	691	4,541	85.62	0.96	6.32
Ohio U.	Public	Doctoral Universities: High Research Activity	195	53,303	1,063	892	4,337	50.14	0.84	4.08
U. North Texas, Health Science Center	Public	Special Focus Four-Year: Medical Schools & Centers	199	49,503	253	107	373	195.66	0.42	1.47
Portland State U.	Public	Doctoral Universities: High Research Activity	202	46,911	904	730	2,531	51.89	0.81	2.80
Florida A&M U.	Public	Doctoral Universities: High Research Activity	214	39,682	620	263	1,479	64.00	0.42	2.39
Lehigh U.	Private	Doctoral Universities: High Research Activity	218	38,674	540	706	3,213	71.62	1.31	5.95
U. California, Merced	Public	Doctoral Universities: High Research Activity	219	38,226	375	610	3,480	101.94	1.63	9.28
U.S. Air Force Academy	Public	Baccalaureate Colleges: Arts & Sciences Focus	223	35,925	214	98	224	167.87	0.46	1.05
Alabama A&M U.	Public	Master's Colleges & Universities: Larger Programs	227	33,524	259	141	1,419	129.44	0.54	5.48
Baylor U.	Private	Doctoral Universities: High Research Activity	235	31,936	1,116	1,196	7,232	28.62	1.07	6.48
U. Massachusetts, Dartmouth	Public	Doctoral Universities: High Research Activity	245	26,626	402	271	1,225	66.23	0.67	3.05
SUNY, C. of Environmental Science and Forestry	Public	Doctoral Universities: High Research Activity	246	26,610	128	217	1,207	207.89	1.70	9.43
California State U., Sacramento	Public	Master's Colleges & Universities: Larger Programs	259	21,429	791	314	2,198	27.09	0.40	2.78
Villanova U.	Private	Doctoral Universities: High Research Activity	267	20,730	710	436	3,738	29.20	0.61	5.26
Fordham U.	Private	Doctoral Universities: High Research Activity	268	20,644	567	639	1,593	36.41	1.13	2.81
U. Tulsa	Private	Doctoral Universities: High Research Activity	270	20,072	356	289	2,057	56.38	0.81	5.78
CUNY, Queens C.	Public	Master's Colleges & Universities: Larger Programs	290	16,676	587	247	542	28.41	0.42	0.92
New York Medical C.	Private	Special Focus Four-Year: Medical Schools & Centers	294	16,226	476	388	4,626	34.09	0.82	9.72
U. Texas Health Science Center, Tyler	Public	Special Focus Four-Year: Other Health Professions Schools	296	15,451	45	27	177	343.36	0.60	3.93
U. New Orleans	Public	Doctoral Universities: High Research Activity	301	14,437	291	156	1,024	49.61	0.54	3.52
Langston U.	Public	Master's Colleges & Universities: Small Programs	330	10,947	122	15	54	89.73	0.12	0.44
U. North Florida	Public	Doctoral/Professional Universities	337	9,994	507	246	798	19.71	0.49	1.57
U. Arkansas, Little Rock	Public	Doctoral Universities: High Research Activity	353	8,167	432	242	631	18.91	0.56	1.46
U. Tennessee, Chattanooga	Public	Doctoral/Professional Universities	364	7,585	481	192	464	15.77	0.40	0.96
Sam Houston State U.	Public	Doctoral/Professional Universities	367	7,152	797	260	535	8.97	0.33	0.67
California State U., Bakersfield	Public	Master's Colleges & Universities: Larger Programs	393	5,577	310	95	584	17.99	0.31	1.88
Williams C.	Private	Baccalaureate Colleges: Arts & Sciences Focus	397	5,506	317	181	425	17.37	0.57	1.34
Texas Woman's U.	Public	Doctoral/Professional Universities	411	4,822	469	173	237	10.28	0.37	0.51
Vassar C.	Private	Baccalaureate Colleges: Arts & Sciences Focus	423	4,185	282	92	357	14.84	0.33	1.27
CUNY, C. Staten Island	Public	Master's Colleges & Universities: Larger Programs	426	4,031	369	168	618	10.92	0.46	1.67
New York Institute of Technology	Private	Master's Colleges & Universities: Larger Programs	431	3,832	325	130	390	11.79	0.40	1.20
Alfred U.	Private	Master's Colleges & Universities: Larger Programs	437	3,641	148	34	156	24.60	0.23	1.05
Appalachian State U.	Public	Master's Colleges & Universities: Larger Programs	438	3,631	1,010	348	993	3.60	0.34	0.98
U. Wisconsin-Stevens Point	Public	Master's Colleges & Universities: Small Programs	453	3,291	359	65	201	9.17	0.18	0.56
Trinity U.	Private	Master's Colleges & Universities: Small Programs	457	3,244	255	112	804	12.72	0.44	3.15
SUNY, C. of Optometry	Public	Special Focus Four-Year: Other Health Professions Schools	464	3,120	71	45	84	43.94	0.63	1.18
U. Northern Iowa	Public	Master's Colleges & Universities: Larger Programs	474	2,983	496	151	309	6.01	0.30	0.62
Grambling State U.	Public	Master's Colleges & Universities: Larger Programs	476	2,981	156	5	7	19.11	0.03	0.04
Murray State U.	Public	Master's Colleges & Universities: Larger Programs	481	2,872	444	125	291	6.47	0.28	0.66
CUNY, Baruch C.	Public	Master's Colleges & Universities: Larger Programs	482	2,817	493	241	606	5.71	0.49	1.23
Fisk U.	Private	Baccalaureate Colleges: Arts & Sciences Focus	484	2,790	59	35	383	47.29	0.59	6.49
Albany C. of Pharmacy and Health Sciences	Private	Special Focus Four-Year: Other Health Professions Schools	489	2,732	88	78	343	31.05	0.89	3.90
Bowdoin C.	Private	Baccalaureate Colleges: Arts & Sciences Focus	490	2,724	222	113	376	12.27	0.51	1.69
Southeastern Louisiana U.	Public	Master's Colleges & Universities: Larger Programs	530	2,039	501	51	117	4.07	0.10	0.23
Calvin C.	Private	Master's Colleges & Universities: Small Programs	536	1,937	232	51	121	8.35	0.22	0.52
SUNY, Buffalo State	Public	Master's Colleges & Universities: Larger Programs	540	1,928	360	2,737	15,517	5.36	7.60	43.10
Middlebury C.	Private	Baccalaureate Colleges: Arts & Sciences Focus	542	1,895	319	116	315	5.94	0.36	0.99
Oberlin C.	Private	Baccalaureate Colleges: Arts & Sciences Focus	547	1,803	321	139	559	5.62	0.43	1.74
Northern Michigan U.	Public	Master's Colleges & Universities: Medium Programs	554	1,728	302	48	116	5.72	0.16	0.38
Coastal Carolina U.	Public	Master's Colleges & Universities: Larger Programs	564	1,631	490	117	275	3.33	0.24	0.56
Saint Michael's C.	Private	Baccalaureate Colleges: Arts & Sciences Focus	578	1,482	125	24	55	11.86	0.19	0.44
U. Wisconsin-Green Bay	Public	Master's Colleges & Universities: Medium Programs	579	1,454	223	18	43	6.52	0.08	0.19
Biola U.	Private	Doctoral/Professional Universities	617	1,085	286	39	34	3.79	0.14	0.12
Augsburg U.	Private	Master's Colleges & Universities: Larger Programs	622	1,051	175	31	100	6.01	0.18	0.57
U. Wisconsin-River Falls	Public	Master's Colleges & Universities: Medium Programs	636	923	212	4	8	4.35	0.02	0.04

5. DATA ANALYSIS

5.1 Analysis of Dataset No. 1

Table 1 showed an average annual increase of 2% in the total fractional publication count (i.e., fractional credit given for a publication for each institution proportion to the participating authors from each institution) beginning FY 2002 and then an average decrease of 1% for FYs 2015, 2016 and 2018. The total whole publication count (i.e., full credit given for a publication for each institution type that is on the author's list) showed an average annual increase of 3% until FY 2017 with a 1% decrease for FY 2018. Finally, the total R&D expenditures showed an average annual increase of 5% from FY 2002 to FY 2018. The relationships among the variables - total R&D expenditures, total whole publication count and total fractional publication count - from the first dataset were tested for statistical significance using regression analysis at the significance value of .05.

The total R&D expenditures and the total whole publication count were first analyzed using the regression data analysis add-in feature in Excel and resulted in an R^2-value of 0.9551 and a significance F of 1.6075×10^{-11}, which meant that there was a statistically significant relationship (See Summary Output in Table 2 and Line Fit Plot in Figure 9). Regression analysis was also done on the total R&D expenditures and the total fractional publication count, and it revealed a statistically significant relationship with an R^2-value of 0.8499 and a significance F of 1.447×10^{-7}, (See Summary Output in Table 3 and Line Fit Plot in Figure 10).

Table 2

Summary Output: Total R&D expenditures and Total Whole Publication Count

Regression Statistics	
Multiple R	0.97730021
R Square	0.95511569
Adjusted R Square	0.95212341
Standard Error	13119.3621
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5.4939E+10	5.4939E+10	319.192536	1.6075E-11
Residual	15	2581764920	172117661		
Total	16	5.752E+10			

Figure 9

Line Fit Plot with Variables: Total R&D expenditures and Total Whole Publication Count

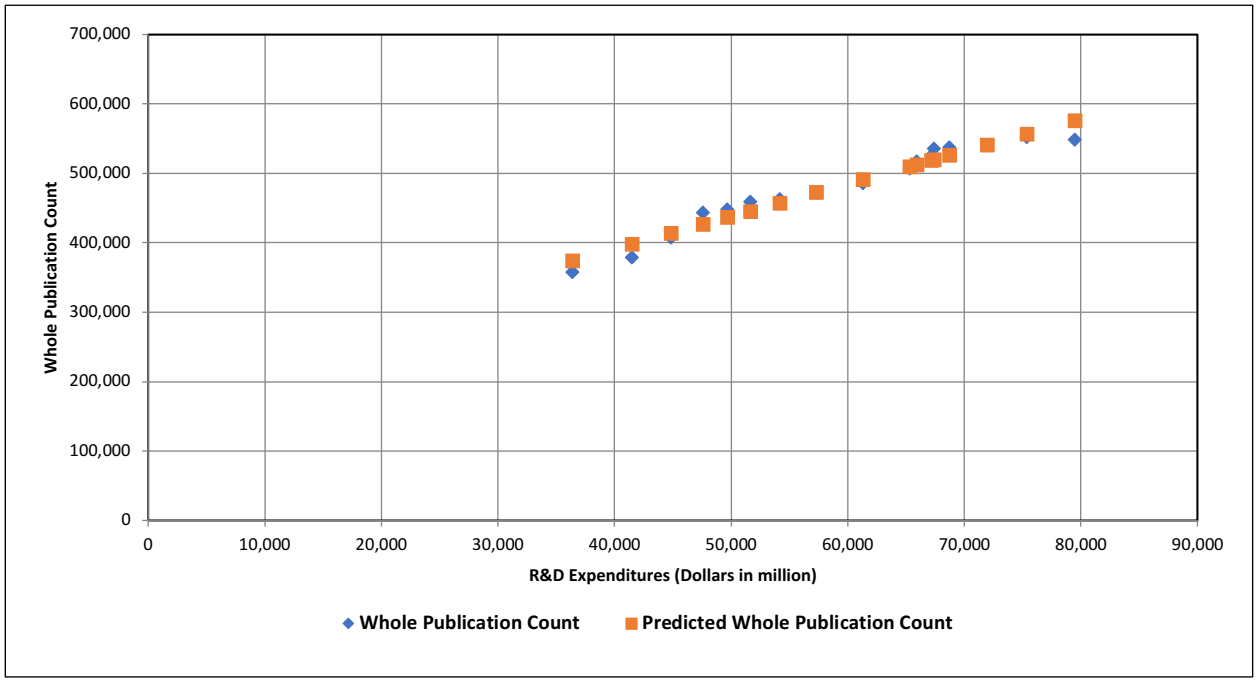


Table 3

Summary Output: Total R&D expenditures and Total Fractional Publication Count

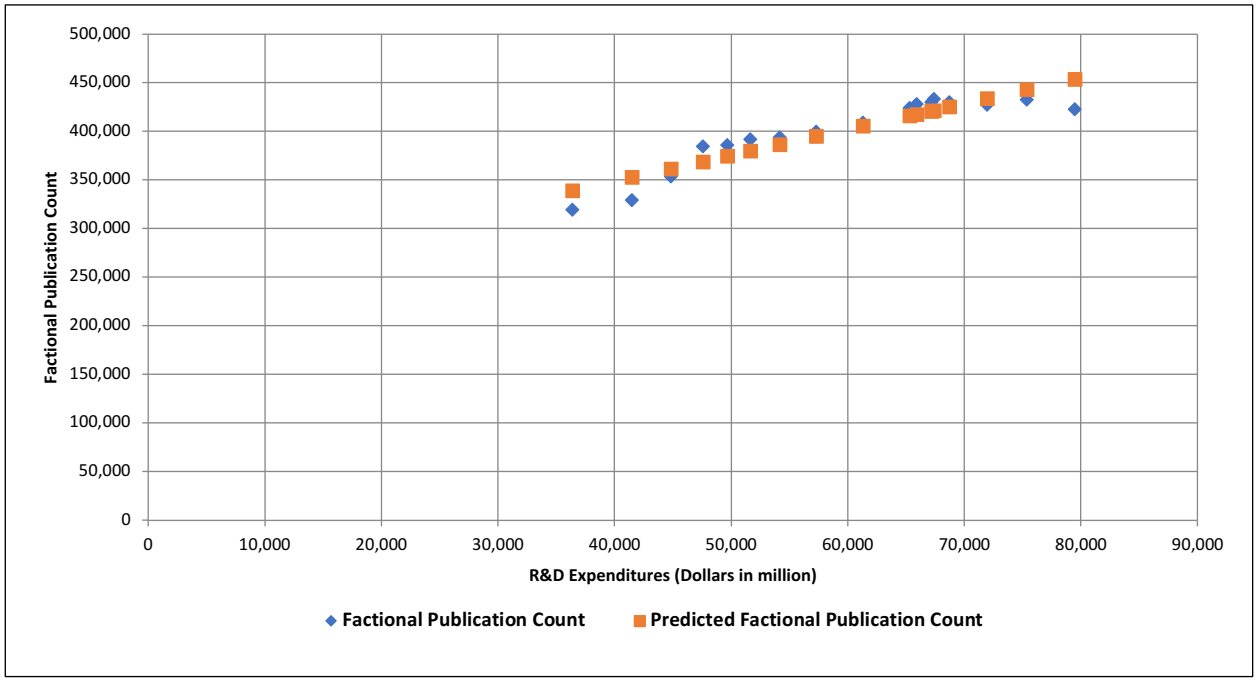
Regression Statistics	
Multiple R	0.92189907
R Square	0.8498979
Adjusted R Square	0.83989109
Standard Error	14422.0399
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.7665E+10	1.7665E+10	84.9319782	1.447E-07
Residual	15	3119928503	207995234		
Total	16	2.0785E+10			

Figure 10

Line Fit plot with Variables: Total R&D Expenditures and Total Fractional Publication Count



5.2 Analysis of Dataset No. 2

The second dataset (Figure 8) was analyzed using regression analysis and was created to look at the per faculty data on R&D expenditures, publications and citation numbers. Regression analysis was first done on the variables: R&D expenditures per faculty and publication per faculty (Web of Science) and returned an R^2-value of 0.4753 and a significance F-value of 7.9147×10^{-12} (see Summary Output in Table 4 and Line Fit Plot in Figure 11), which was less than the significance value of .05, thus indicating a statistically significant relationship between R&D expenditures per faculty and publication per faculty (Web of Science). The next variables that were tested were: R&D expenditures per faculty and citation per faculty (see Summary Output in Table 5 and Line Fit Plot in Figure 12). The resulting R^2-value was 0.7992 and the significant F-value was 3.7129×10^{-27} demonstrated a statistically significant relationship existed.

Table 4

Summary Output: R&D expenditures per Faculty and Publication per Faculty (Web of Science)

Regression Statistics	
Multiple R	0.68947798
R Square	0.47537989
Adjusted R Square	0.46819331
Standard Error	0.95596725
Observations	75

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	60.4511766	60.4511766	66.1483069	7.9147E-12
Residual	73	66.7127565	0.91387338		
Total	74	127.163933			

Figure 11

Line Fit Plot with Variables: R&D Expenditures per Faculty and Publication per Faculty (Web of Science)

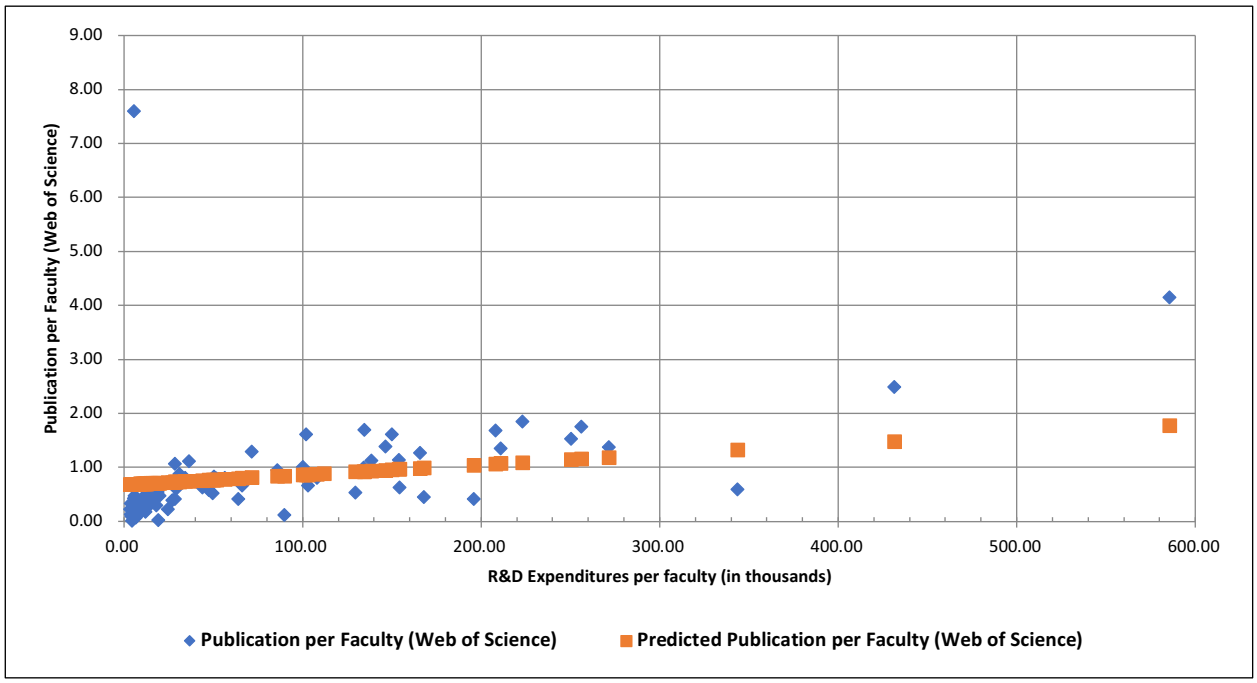


Table 5

Summary Output: R&D expenditures per Faculty and Citation per Faculty (Web of Science)

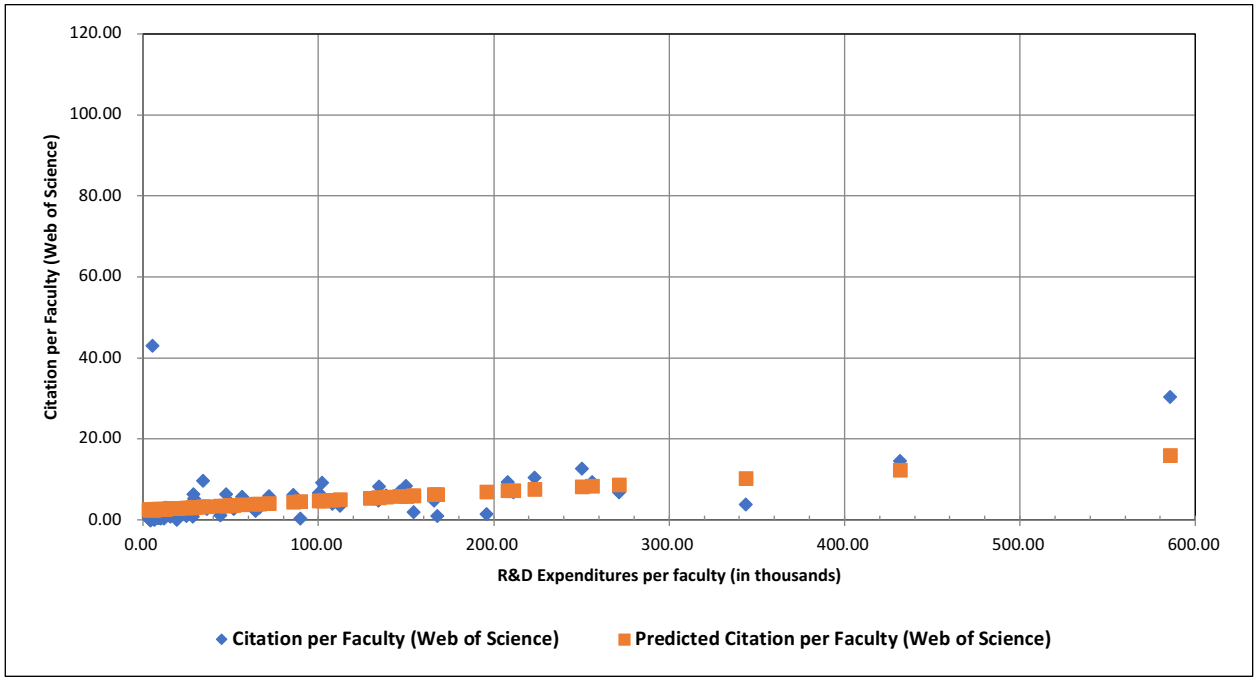
Regression Statistics	
Multiple R	0.89395993
R Square	0.79916435
Adjusted R Square	0.79641318
Standard Error	5.57916171
Observations	75

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9041.82423	9041.82423	290.481288	3.7129E-27
Residual	73	2272.27431	31.1270454		
Total	74	11314.0985			

Figure 12

Line Fit Plot with Variables: R&D Expenditures per Faculty and Citation per Faculty (Web of Science)



6. DISCUSSION OF DATA RESULTS

6.1 Research Objectives

The two research objectives for this thesis were to first explore research productivity at the institutional level by examining R&D expenditures and publication output and then to also explore research productivity at the faculty level by looking at a faculty member's publication output, citations of the publications and R&D expenditures. The regression analyses revealed that there were direct correlations between R&D expenditures and publication numbers at the institutional level and between R&D expenditures, publication numbers and citation numbers at the per faculty level.

6.2 Discussion: Dataset No. 1

The first dataset, shown in Table 1, looked at research productivity at the institutional level for FY 2002 to 2018 by examining the total R&D expenditures and total publication count. The regression analysis on the first dataset revealed that there were positive significant relationships among the variables: Total R&D Expenditures, Total Whole Publication Count and Total Fractional Publication Count. The analysis further revealed that the total R&D expenditures was predictive of the total whole publication count and total fractional publication count. Therefore, R&D expenditures were strongly related with scientific literatures or publications. These positive relationships suggest that institutions getting more funding generate more publications. Therefore, the investment in funding pays off by increasing the productivity of the institution.

However, it was surprising to see such a high R^2 values from the analysis on the first dataset since the publication counts were relatively flat beginning FY 2011 with dips in FYs 2015, 2016, 2018 while total R&D expenditures showed an average annual increase of 5%.

There were some possible reasons for those flat years and dips in publications. One of those reasons could be due to the time lag from R&D expenditures to project completion to actual publications. Another reason could be the R&D expenditures were for research activities that may not result in peer-reviewed publications (e.g. conference and training grants). One other reason could be an institution's shifting priorities (e.g., commercializing basic research) on research funding and activities, emphasizing patents, technology and product development as a way to diversify its core revenue.

6.3 Discussion: Dataset No. 2

The second dataset, shown in Figure 8, explored research productivity by looking at the per faculty data in R&D expenditures, publications and citations. The analyses revealed that there were positive significant relationships and that the R&D expenditures per faculty was predictive of publications per faculty and citations per faculty. So, a faculty member's R&D funding was strongly associated with more publications (output) and citations (impact). These positive relationships suggest that researchers receiving more funding are generating more publications and those publications are being cited by other researchers more often. This also shows that those researchers successfully winning more funding are both more productive and have a greater impact

Although R&D expenditures was predictive of publications and citations per faculty, those relationships should be interpreted cautiously. As previously discussed, citations have peculiar characteristics. For example, older publications will have more time to accumulate the necessary citation counts as opposed to the newer publications. Another example is a faculty member could engage in self-citation where the faculty member cites his/her own work excessively to drive up his/her citation counts. A faculty member can manipulate how he

published, for example, publishing the same scientific results/finding in different journals. Another example is “salami slicing” where the scientific results/findings are broken up into sections and those individual sections are publish in different journals.

6.4 Closing Statement

In the end, R&D expenditures, publications and citations are just some of the indicators for examining research/academic productivity. It is possible for a faculty member without R&D funding to have high publication and citation numbers while also contributing to an institution’s publication and citation numbers as they may have other types of support instead of R&D funding, such as equipment loan, laboratory space usage and availability of special reagents or software, to perform research activities. They can also seek out available publication funding assistance in their institutions to support their publishing efforts. Another possibility is that they could agree to collaborate with colleagues who have R&D funding and publish the research findings jointly. Finally, faculty members can be selective in their choice of journals (e.g., high impact journals) for publishing their research and thus generating citations for those publications.

7. CONCLUSION

7.1 Finals Results

This study revealed statistically significant relationships existed among the variables for both datasets (Table 1 and Figure 8) which meant that one variable was strongly associated with the other variables. The more interesting relationship to take note of was in the per faculty data, shown in Figures 11 and 12, on publications (output) and citations (impact) as it revealed that R&D expenditures per faculty were predictive of publications per faculty and citations per faculty.

7.2 Final Thoughts

These positive relationships made sense since more productive research institutions and faculty members who received more R&D expenditures would have more publications and generate more citations for those publications. Consequently, research institutions and faculty members who had track records of being successful in receiving R&D funding are more likely to continue to be successful. However, this could create a "Matthew effect" meaning that a faculty member's past success in receiving R&D funding has a positive effect for future funding, so the concentration of R&D funding is directed or allocated only to those who in past were successful. This could also create a fierce competitive research environment in a declining and an uncertain funding landscape and faculty members who were unsuccessful in the past may be discouraged to try to break into the process of getting R&D funding. Research institutions may need look at their resource allocation process so that financial resources are distributed to a wider range of researchers as a push and to encourage them to seek out R&D funding which could drive up publication numbers and eventually citation numbers.

7.3 Future Studies and Actions

This study also provided important insights by exploring one critical aspect of a faculty member's productivity through R&D expenditures and limiting to peer-reviewed publications. It is important to acknowledge that a faculty member could also be productive in other critical aspects, such as teaching, public service and mentorship of undergraduate and graduate students and post-doctoral scholars. Therefore, these are some aspects with other document types (e.g., abstracts, book chapters and books) that should be explored in future studies to see the whole picture. To that end, research productivity should be explored with objectivity as R&D expenditures, publications and citations counts are just some of the variables that can be used as measures. These variables should be implemented with others, such as the total numbers of proposals submitted, patents, teaching, mentoring and peer review activities, to appropriately measure a faculty member's research output and impact while providing a meaningful and compelling story of a faculty member's academic performance.

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CURRICULUM VITAE

Yoke Dellenback
Research Administrator
University of California Davis
Davis, CA 95616
Telephone: (530) 752-3146
Email: ypdellenback@ucdavis.edu

Professional Profile

Research administrator with over 15 years of experience supporting faculty members, researchers and graduate students with pre- and post-award logistics in contracts and grants.

Education

Singapore Polytechnic	Singapore	Building Technology	Diploma Spring 1990
Information Computer School	Singapore	Computer Studies	Advanced Diploma Fall 1991
San Jose State University	San Jose, CA	Environmental Studies	Bachelor of Science Fall 1997
Johns Hopkins University	Baltimore, MD	Research Administration	Master of Science Fall 2020

Certifications

Research Administrators Certification Council	Certified Research Administrator	May 2012
Research Administrators Certification Council	Certified Pre-Award Research Administrator	Sept 2013
Research Administrators Certification Council	Certified Financial Research Administrator	May 2015

Work Experience

Dec 2010 – Present

University of California, Davis • Research Administrator 4

- Provide recommendations and implementation of new procedures to improve business processes through analysis and creative solution design and identify individual training needs and provide guidance and training on all aspects concerning contracts and grants
- Provide direction for all divisional research and special accounts including purchase approval, re-budgeting and closure, transfer of funds, and approval, initiation and/or supervision of financial transactions
- Establish a departmental budget review process to analyze and assess budget submissions according to impact, type of funding, and alignment with any existing programmatic objectives
- Interpret funding source guidelines and advise faculty, principal investigators and divisional personnel regarding proper account management required by University and sponsors

Apr 2008 – Dec 2010

University of California, Davis • Business Office Manager

- Prepared all grant proposals and contracts for paper submission and electronic submission to various private, state and federal sponsors
- Responsible for coordinating and administering all the department's grants and contracts activities
- Provided analyses of department's base/current funding, contracts and grants activities, recharge operation and rate schedules

Nov 2006 – Apr 2008

University of California, Davis • Account Manager

- Prepared all grant proposals and contracts for paper submission and electronic submission systems to various private, state and federal sponsors
- Acted as fiscal officer for numerous extramural accounts and for the department's recharge account
- Acted as a resource for Department Chair and MSO regarding staff appraisal, merit and promotion review process, and recruitment in matters of policy and procedure interpretation

Professional Affiliations

2011–Present	Member	National Council of University Research Administrators (NCURA)
2012–Present	Member	Society for Research Administrators International (SRAI)